DC-DC Converter Applications

Content

- Terminology
  - Input Range
  - Load Regulation
  - Line Voltage Regulation
  - Output Voltage Accuracy
  - Input and Output Ripple and Noise
  - Input to Output Isolation
  - Insulation Resistance
  - Efficiency at Full Load
  - Temperature Drift
  - Switching Frequency
  - No Load Power Consumption
  - Isolation Capacitance
  - Mean Time Between Failure (MTBF)
  - Noise
  - Operating Temperature Range
  - Calculation of Heatsinks

- Isolation
  - Isolation Voltage vs. Rated Working Voltage
  - Isolation mode in IGBT Driver Circuits
  - Connecting DC-DC Converters in Series
  - Connecting DC-DC Converters in Parallel

- Filtering
  - Output Filtering Calculation

- Limiting Inrush Current

- Maximum Output Capacitance

- Settling Time

- Isolation Capacitance and Leakage Current

- Application Examples
  - Overload Protection
  - Input Voltage Drop-Out (brown-outs)
  - No Load Over Voltage Lock-Out

- Long Distance Supply Lines
- LCD Display Bias
- EIA-232 Interface
- 3V/5V Logic Mixed Supply Rails
- Isolated Data Acquisition System

- EMC Considerations
  - Power Supply Considerations
  - Interpretation of DC-DC Converter EMC Data
  - Conducted and Radiated Emissions
  - Line Impedance Stabilisation Network (LISN)

- Line Spectra of DC-DC Converters

- Temperature Performance of DC-DC Converters

- Transfer Moulded (SMD) DC-DC Converters

- Production Guideline Application Note
- Component Materials
- Component Placement
- Component Alignment
- Solder Pad Design
- Solder Reflow Profile
- Recommended Solder Reflow Profile
- Adhesive Requirements
- Adhesive Placement
- Cleaning
- Vapour Phase Reflow Soldering

Powerline – Definitions and Testing

- EMC Filter Suggestion
- General Test Set-Up
- Input Voltage Range
- PI Filter
- Output Voltage Accuracy
- Voltage Balance
- Line Regulations
- Load Regulation
- Efficiency
- Switching Frequency

- Transient Recovery Time
- Current Limiting
- Fold Back Current Limiting
- Isolation
- Break-Down Voltage
- Temperature Coefficient
- Ambient Temperature
- Operating Temperature Range
- Storage Temperature Range
- Output Voltage Trimming
DC-DC Converter Applications

Terminology
The data sheet specification for DC-DC converters contains a large quantity of information. This terminology is aimed at ensuring that the user can interpret the data provided correctly and obtain the necessary information for their circuit application.

Input Range
The range of input voltage that the device can tolerate and maintain functional performance over the Operating Temperature Range at full load.

Load Regulation
The change in output voltage over the specified change in output load. Usually specified as a percentage of the nominal output voltage, for example, if a 1V change in output voltage is measured on a 12V output device, load voltage regulation is 8.3%. For unregulated devices the load voltage regulation is specified over the load range from 10% to 100% of full load.

Line Voltage Regulation
The change in output voltage for a given change in input voltage, expressed as percentages. For example, assume a 12V input, 5V output device exhibited a 0.5V change at the output for a 1.2V change at the input, line regulation would be 1%/1%.

Output Voltage Accuracy
The proximity of the output voltage to the specified nominal value. This is given as a tolerance envelope for unregulated devices with the nominal input voltage applied. For example, a 5V specified output device at 100% load may exhibit a measured output voltage of 4.75V, i.e. a voltage accuracy of ~5%.

Input and Output Ripple and Noise
The amount of voltage drop at the input, or output between switching cycles. The value of voltage ripple is a measure of the storage ability of the filter capacitors. The values given in the datasheets include the higher frequency Noise interference superimposed on the ripple due to switching spikes. The measurement is limited to 20MHz Bandwidth.

Input to Output Isolation
The dielectric breakdown strength test between input and output circuits. This is the isolation voltage the device is capable of withstanding for a specified time, usually 1 second (for more details see chapter “Isolation Voltage vs. Rated Working Voltage”).

Insulation Resistance
The resistance between input and output circuits. This is usually measured at 500V DC isolation voltage.

Efficiency at Full Load
The ratio of power delivered from the device to power supplied to the device when the part is operating under 100% load conditions at 25°C.

Temperature Drift
The change in voltage, expressed as a percentage of the nominal, per degree change in ambient temperature. This parameter is related to several other temperature dependent parameters, mainly internal component drift.

Switching Frequency
The nominal frequency of operation of the switching circuit inside the DC-DC converter. The ripple observed on the input and output pins is usually twice the switching frequency, due to full wave rectification and the push-pull configuration of the driver circuit.

No Load Power Consumption
This is a measure of the switching circuits power consumption; it is determined with zero output load and is a limiting factor for the total efficiency of the device.

Isolation Capacitance
The input to output coupling capacitance. This is not actually a capacitor, but the parasitic capacitive coupling between the transformer primary and secondary windings. Isolation capacitance is typically measured at 1 MHz to reduce the possibility of the onboard filter capacitors affecting the results.

Mean Time Between Failure (MTBF)
RECOM uses MIL-HDBK-217F standard for calculation of MTBF values for +25°C as well as for max. operating temperature and 100% load. When comparing MTBF values with other vendor’s products, please take into account the different conditions and standards i.e. MIL-HDBK-217E is not as severe and therefore values shown will be higher than those shown by RECOM. (1000 x 10³ hours = 1000000 hours = 114 years!) These figures are calculated expected device lifetime figures using the hybrid circuit model of MIL-HDBK-217F: POWERLINE converters also can use BELLCORE TR-NWT-000332 for calculation of MTBF. The hybrid model has various accelerating factors for operating environment (σE), maturity (σL), screening (σQ), hybrid function (σF) and a summation of each individual component characteristic (λC).

The equation for the hybrid model is then given by:

\[ \lambda = \sum (N_C \lambda_C) (1 + 0.2\pi_E) \pi_L \pi_F \pi_Q \]

(fails in 10⁶ hours)

The MTBF figure is the reciprocal of this value. In the data sheets, all figures for MTBF are given for the ground benign (GB) environment (σE = 0.5); this is considered the most appropriate for the majority of applications in which these devices are likely to be used. However, this is not the only operating environment possible, hence those users wishing to incorporate these devices into a more severe environment can calculate the predicted MTBF from the following data.

The MIL-HDBK-217F has military environments specified, hence some interpretation of these is required to apply them to standard commercial environments. Table 1 gives approximate cross references from MIL-HDBK-217F descriptions to close commercial equivalents. Please note that these are not implied by MIL-HDBK-217F, but are our interpretation. Also we have reduced the number of environments from 14 to 6, which are most appropriate to commercial applications. For a more detailed understanding of the environments quoted and the hybrid model, it is recommended that a full copy of MIL-HDBK-217F is obtained.

It is interesting to note that space flight and ground benign have the same environment factors. It could be suggested that the act of achieving space flight should be the determining environmental factor (i.e. missile launch). The hybrid model equation can therefore be rewritten for any given hybrid, at a fixed temperature, so that the environmental factor is the only variable:

\[ \lambda = k (1 + 0.2 \pi_E) \]

The MTBF values for other environment factors can therefore be calculated from the ground benign figure quoted at each temperature point in the data book. Hence predicted MTBF figures for other environments can be calculated very quickly. All the values will in general be lower and, since the majority of the mobile environments have the same factor, a quick divisor can be calculated for each condition. Therefore the only calculation necessary is to divide the quoted MTBF fig. by the divisor given in table 2.
DC-DC Converter Applications

<table>
<thead>
<tr>
<th>Environment</th>
<th>πE Symbol</th>
<th>MIL-HDBK-271F Description</th>
<th>Commercial Interpretation or Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Benign</td>
<td>GB</td>
<td>Non-mobile, temperature and humidity controlled environments readily accessible to maintenance</td>
<td>Laboratory equipment, test instruments, desktop PC's, static telecomms</td>
</tr>
<tr>
<td>Ground Mobile</td>
<td>GM</td>
<td>Equipment installed in wheeled or tracked vehicles and equipment manually transported</td>
<td>In-vehicle instrumentation, mobile radio and telecomms, portable PC's</td>
</tr>
<tr>
<td>Naval Sheltered</td>
<td>NS</td>
<td>Sheltered or below deck equipment on surface ships or submarines</td>
<td>Navigation, radio equipment and instrumentation below deck</td>
</tr>
<tr>
<td>Aircraft Inhabited Cargo</td>
<td>AIC</td>
<td>Typical conditions in cargo compartments which can be occupied by aircrew</td>
<td>Pressurised cabin compartments and cock-pit, in flight entertainment and non-safety critical applications</td>
</tr>
<tr>
<td>Space Flight</td>
<td>SF</td>
<td>Earth orbital. Vehicle in neither powered flight nor in atmospheric re-entry</td>
<td>Orbital communications satellite, equipment only operated once in-situ</td>
</tr>
<tr>
<td>Missile Launch</td>
<td>ML</td>
<td>Severe conditions relating to missile launch</td>
<td>Severe vibrational shock and very high accelerating forces, satellite launch conditions</td>
</tr>
</tbody>
</table>

Table 1: Interpretation of Environmental Factors

<table>
<thead>
<tr>
<th>Environment</th>
<th>πE Symbol</th>
<th>πE Value</th>
<th>Divisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Benign</td>
<td>GB</td>
<td>0.5</td>
<td>1.00</td>
</tr>
<tr>
<td>Ground Mobile</td>
<td>GM</td>
<td>4.0</td>
<td>1.64</td>
</tr>
<tr>
<td>Naval Sheltered</td>
<td>GNS</td>
<td>4.0</td>
<td>1.64</td>
</tr>
<tr>
<td>Aircraft Inhabited Cargo</td>
<td>AIC</td>
<td>4.0</td>
<td>1.64</td>
</tr>
<tr>
<td>Space Flight</td>
<td>SF</td>
<td>0.5</td>
<td>1.00</td>
</tr>
<tr>
<td>Missile Launch</td>
<td>ML</td>
<td>12.0</td>
<td>3.09</td>
</tr>
</tbody>
</table>

Table 2: Environmental Factors

Noise
Input conducted noise is given in the line conducted spectra for each DC-DC converter (see EMC issues for further details). Noise is affected significantly by PCB layout, measurement system configuration, terminating impedance etc., and is difficult to quote reliably and with any accuracy other than via a spectrum analysis type plot. There will be some switching noise present on top of the ripple, however, most of this is easily reduced by use of small capacitors or filter inductors, as shown in the application notes.

Operating temperature range:
Operating temperature range of the converter is limited due to specifications of the components used for the internal circuit of the converter.

The diagram for temperature derating shows the safe operating area (SOA) within which the device is allowed to operate. At very low temperatures, the specifications are only guaranteed for full load.

Up to a certain temperature 100% power can be drawn from the device, above this temperature the output power has to be less to ensure function and guarantee specifications over the whole lifetime of the converter.

These temperature values are valid for natural convection only. If the converter is used in a closed case or in a potted PCB board, higher temperatures will be present in the area around thermal converter because the convection may be blocked.

If the same power is also needed at higher temperatures either the next higher wattage series should be chosen or if the converter has a metal case, a heatsink may be considered.

Calculation of heatsinks:
All converters in metal-cases can have a heatsink mounted so the heat generated by the converters internal power dissipation Pd can be removed. The general specification of the whole thermal system including the converter is its thermal resistance RTH case-ambient.

\[
\text{Power dissipation } P_d = P_{\text{in}} - P_{\text{out}} = \frac{P_{\text{out}}}{\text{Efficiency}} - P_{\text{out}}
\]

\[
R_{\text{TH case-ambient}} = \frac{T_{\text{case}} - T_{\text{ambient}}}{P_d}
\]

Figure 1: Standard Isolated Configurations

Figure 2: Alternative Supply Configurations
Isolation

One of the main features of the majority of Recom International Power GmbH DC-DC converters is their high galvanic isolation capability. This allows several variations on circuit topography by using a single DC-DC converter.

The basic input to output isolation can be used to provide either a simple isolated output power source, or to generate different voltage rails, and/or dual polarity rails (see figure 1).

These configurations are most often found in instrumentation, data processing and other noise sensitive circuits, where it is necessary to isolate the load and noise presented to the local power supply rails from that of the entire system. Usually local supply noise appears as common mode noise at the converter and does not pollute the main system power supply rails.

The isolated positive output can be connected to the input ground rail to generate a negative supply rail if required. Since the output is isolated from the input, the choice of reference voltage for the output side can be arbitrary, for example an additional single rail can be generated above the main supply rail, or offset by some other DC value (see figure 2).

Heatsink mounted on case without thermal conductivity paste

\[ R_{\text{TH case-heatsink}} = \text{ca. 1...2 °C/W} \]

Heatsink mounted on case with thermal conductivity paste

\[ R_{\text{TH case-heatsink}} = \text{ca. 0,5...1 °C/W} \]

Heatsink mounted on case with thermal conductivity paste and electrical-isolation-film

\[ R_{\text{TH case-heatsink}} = \text{ca. 1...1,5 °C/W} \]

So it has to be ensured that the thermal resistance between case and ambient is 6,1 °C/W max.

When mounting a heatsink on a case there is a thermal resistance \( R_{\text{TH case-heatsink}} \) between case and heatsink which can be reduced by using thermal conductivity paste but cannot be eliminated totally.

\[ R_{\text{TH case-heatsink}} = R_{\text{TH case-heatsink (min)\_ambient}} \]

Using this value, a suitable heat sink can be selected.

Adding a fan increases the efficiency of any additional heat sinking, but adds cost and power loading.

In most cases choosing the next higher wattage-series and using power-decreasing via derating may be the more efficient solution.

Efficiency = 88% max.

\[ R_{\text{TH case-heatsink}} = \frac{P_{\text{out}}}{P_{\text{in}}} = \frac{30 \text{ W}}{30 \text{ W}} = 100 \% \]

\[ T_{\text{in}} = 100 \ ^\circ \text{C} \text{ (max. allowed case temperature)} \]

\[ T_{\text{ambient}} = 75 \ ^\circ \text{C} \]

\[ R_{\text{TH case-ambient}} = \frac{T_{\text{in}} - T_{\text{ambient}}}{P_{\text{out}}} = \frac{100 \ ^\circ \text{C} - 75 \ ^\circ \text{C}}{4,1 \text{ W}} = 6,1 \ ^\circ \text{C/W} \]

If a heatsink is mounted on the converter it’s thermal resistance has to be at least:

\[ R_{\text{TH case-ambient}} = R_{\text{TH case-heatsink (min)\_ambient}} + R_{\text{TH heat sink-ambient}} \]

\[ R_{\text{TH heat sink-ambient}} = \frac{T_{\text{in}} - T_{\text{ambient}}}{P_{\text{out}}} = \frac{100 \ ^\circ \text{C} - 75 \ ^\circ \text{C}}{4,1 \text{ W}} = 6,1 \ ^\circ \text{C/W} \]

\[ R_{\text{TH heat sink-ambient}} = 5,1 \ ^\circ \text{C/W} \]

Isolation Voltage vs. Rated Working Voltage

The isolation voltage given in the datasheet is valid for 1 second flash tested only. If a isolation barrier is required for longer or infinite time the Rated Working Voltage has to be used.

Conversion of Isolation Voltage to Rated Working Voltage can be done by using this table or graph.

<table>
<thead>
<tr>
<th>Isolation Test Voltage (V)</th>
<th>Rated Working Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>130</td>
</tr>
<tr>
<td>1500</td>
<td>230</td>
</tr>
<tr>
<td>3000</td>
<td>1100</td>
</tr>
<tr>
<td>6000</td>
<td>3050</td>
</tr>
</tbody>
</table>

Table 2: Typical Breakdown Voltage Ratings According to IEC950
DC-DC Converter Applications

The graph and table above show the requirements from IEC950. According to our experience and in-house-test, we can offer the following conversion tables:

### Table 1: D.C. Isolation Voltage test vs different conditions

<table>
<thead>
<tr>
<th>Isolation Test Voltage (1 second)</th>
<th>Isolation Test Voltage (1 minute)</th>
<th>Isolation Test Voltage (1 minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 VDC</td>
<td>400 VDC</td>
<td>250 VAC</td>
</tr>
<tr>
<td>1000 VDC</td>
<td>800 VDC</td>
<td>500 VAC</td>
</tr>
<tr>
<td>1500 VDC</td>
<td>1200 VDC</td>
<td>750 VAC</td>
</tr>
<tr>
<td>2000 VDC</td>
<td>1600 VDC</td>
<td>1000 VAC</td>
</tr>
<tr>
<td>2500 VDC</td>
<td>2000 VDC</td>
<td>1250 VAC</td>
</tr>
<tr>
<td>3000 VDC</td>
<td>2400 VDC</td>
<td>1500 VAC</td>
</tr>
<tr>
<td>4000 VDC</td>
<td>3200 VDC</td>
<td>2000 VAC</td>
</tr>
<tr>
<td>5000 VDC</td>
<td>4000 VDC</td>
<td>2500 VAC</td>
</tr>
<tr>
<td>6000 VDC</td>
<td>4800 VDC</td>
<td>3000 VAC</td>
</tr>
</tbody>
</table>

### Table 2: A.C. Isolation Voltage test vs different conditions

<table>
<thead>
<tr>
<th>Isolation Test Voltage (1 second)</th>
<th>Isolation Test Voltage (1 minute)</th>
<th>Isolation Test Voltage (1 minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 VAC</td>
<td>350 VAC</td>
<td>565 VDC</td>
</tr>
<tr>
<td>1000 VAC</td>
<td>700 VAC</td>
<td>1130 VDC</td>
</tr>
<tr>
<td>1500 VAC</td>
<td>1050 VAC</td>
<td>1695 VDC</td>
</tr>
<tr>
<td>2000 VAC</td>
<td>1400 VAC</td>
<td>2260 VDC</td>
</tr>
<tr>
<td>2500 VAC</td>
<td>1750 VAC</td>
<td>2825 VDC</td>
</tr>
<tr>
<td>3000 VAC</td>
<td>2100 VAC</td>
<td>3390 VDC</td>
</tr>
<tr>
<td>4000 VAC</td>
<td>2800 VAC</td>
<td>4520 VDC</td>
</tr>
<tr>
<td>5000 VAC</td>
<td>3500 VAC</td>
<td>5650 VDC</td>
</tr>
<tr>
<td>6000 VAC</td>
<td>4200 VAC</td>
<td>6780 VDC</td>
</tr>
</tbody>
</table>

Isolation mode in IGBT driver circuits

DC/DC converters may be used in driver circuits for IGBT stacks. In these applications, an additional source of stress has to be considered. Not only the permanently high isolation voltage requiring a high rated working voltage for the converter is present, but also the highly dynamic switching is a stressing factor - this can reach 20kV/µs and more! Taking into account that both factors mean a permanent stress to the converter for all of it’s lifetime, it is recommended to overspec the converter in terms of isolation - i.e. even if a 3kVDC (for 2 second) product seems to fit if you look at just the rated working voltage that is required, it still is recommended to choose a product which is specified for 5,2kVDC or 6kVDC (for 1 second) to cover also the high dv/dt. The higher the isolation voltage rating for a DC/DC converter is, the lower the coupling (isolation) capacitance and a low coupling capacitance is essential in AC or highly dynamic switched DC usage. This will ensure a safe usage and avoid a shortened lifetime in such a highly demanding situation.
Connecting DC-DC Converters in Series

Galvanic isolation of the output allows multiple converters to be connected in series, simply by connecting the positive output of one converter to the negative of another (see figure 3). In this way non-standard voltage rails can be generated, however, the current output of the highest output voltage converter should not be exceeded.

When converters are connected in series, additional filtering is strongly recommended, as the converters switching circuits are not synchronised. As well as a summation of the ripple voltages, the output could also produce relatively large beat frequencies. A capacitor across the output will help, as will a series inductor (see filtering).

Connecting DC-DC Converters in Parallel

Connecting the outputs of DC/DC converters in parallel is possible but not recommended. Usually DC/DC converters have no possibility to balance out the output currents. So there is potential danger that if the loading is asymmetrical, that one of the converters starts to be overloaded while the others have to deliver less current. The overloaded converter may then drop out of circuit leading to power supply oscillation.

The only possibility to balance out the individual currents is to use a special balance function (like in R-5xxx) or use converters with SENSE function and additional load-share-controllers (as can be done for RP40-xxxxSG).

Figure 3: Connecting DC-DC Converters in Series

Figure 4: Paralleled DC-DC Converters with Balance Function.

Figure 5: Paralleled DC-DC Converters using Load Share Controllers
Filtering

When reducing the ripple from the converter, at either the input or the output, there are several aspects to be considered. Recom recommend filtering using simple passive LC networks at both input and output (see figure 6). A passive RC network could be used, however, the power loss through a resistor is often too high. The self-resonant frequency of the inductor needs to be significantly higher than the characteristic frequency of the device (typically 100kHz for Recom DC-DC converters). The DC current rating of the inductor also needs consideration, a rating of approximately twice the supply current is recommended.

The DC resistance of the inductor is the final consideration that will give an indication of the DC power loss to be expected from the inductor.

**Output Filtering calculation:**

Calculating of the filtering components can be done using

\[ f_c = \frac{1}{2\pi \sqrt{L_{out}C_0}} \]

This frequency should be significant lower than the switching frequency of the converter.

Example - RC series:
Operating frequency = 85kHz max.

\[ f_c = \frac{1}{2\pi \sqrt{\frac{L_{out}}{C_0}}} \]

\[ f_c = 8.5\text{ kHz} = \frac{1}{2\pi \sqrt{\frac{L_{out}}{C_0}}} \]

for:
\[ L_{out} = 470\text{ µH} \]

\[ C_0 = \left( \frac{1}{2\pi} \right)^2 \left( \frac{1}{(2\pi \times 8.5\text{ kHz}^2 	imes 470\text{ µH})} \right) = 745\text{ nF} \]

If we consider the circuit without the series inductor, then the input current is given by;

\[ i = \frac{V}{R} \exp \left( -\frac{t}{RC} \right) \]

When the component is initially switched on (i.e. \( t=0 \)) this simplifies to;

\[ i = \frac{V}{R} \]

This would imply that for a 5V input, with say 50mOhm track and wire resistance, the inrush current could be as large as 100A. This could cause a problem for the DC-DC converter.

A series input inductor therefore not only filters the noise from the internal switching circuit, but also limits the inrush current at switch on.

**Limiting Inrush Current**

Using a series inductor at the input will limit the current that can be seen at switch on (see figure 7).

\[ C_0 = \left( \frac{1}{(2\pi f_c L_{out})} \right) = \frac{1}{\left( 2\pi \times 8.5\text{ kHz} \times 470\text{ µH} \right)} = 745\text{ nF} \]
Maximum Output Capacitance

A simple method of reducing the output ripple is simply to add a large external capacitor. This can be a low cost alternative to the LC filter approach, although not as effective. There is also the possibility of causing start up problems, if the output capacitance is too large.

With a large output capacitance at switch on, there is no charge on the capacitors and the DC-DC converter immediately experiences a large current demand at its output. The inrush current can be so large as to exceed the ability of the DC-DC converter, and the device can go into current limit or an undefined mode of operation. In the worst case scenario the device continuously “hiccups” as it tries to start, goes into overload shutdown and then retries again.

The DC-DC converter may not survive if this condition persists.

For the Powerline the maximum capacitive loads are specified. For Econoline please refer to the tables below.

If instead of single capacitors on outputs a L-C-filter is used the max. capacitive load can be higher because the choke is preventing too high rising speed of the current peak. However the achievable max. cap. load is depending on the quality of the filter and the ESR of the capacitors.

Setting Time

The main reason for not fitting a series inductor internally, apart from size constraints, is that many applications require a fast switch on time. When the input voltage is a fast ramp, then the output can respond within 500μs of the input reaching its target voltage (measured on a range of RA/RB and RC/RD converters under full output load without external filters). The use of external filters and additional input or output capacitance will slow this reaction time. It is therefore left to the designer to decide on the predominant factors important for their circuit, settling time or noise performance.

Isolation Capacitance and Leakage Current

The isolation barrier within the DC-DC converter has a capacitance, which is a measure of the coupling between input and output circuits. Providing this is the largest coupling source, a calculation of the leakage current between input and output circuits can be calculated.

Max. capacitive load for unregulated Econoline models

<table>
<thead>
<tr>
<th>Unregulated 0.25W Unregulated 0.5W</th>
<th>Single Output</th>
<th>Dual Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.7μF max.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unregulated 1W Regulated 0.5W Unregulated 1.25W</th>
<th>Single Output</th>
<th>Dual Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.8μF max.</td>
<td>3.3μF max.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unregulated 1.5W Unregulated 2W Regulated 1W</th>
<th>Single Output</th>
<th>Dual Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>10μF max.</td>
<td>6.8μF max.</td>
<td></td>
</tr>
</tbody>
</table>

Max. capacitive load for REC2.2 series

<table>
<thead>
<tr>
<th>2.2W</th>
<th>Single output</th>
<th>Dual output</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3V</td>
<td>1000μF</td>
<td></td>
</tr>
<tr>
<td>5.0V</td>
<td>470μF</td>
<td></td>
</tr>
<tr>
<td>9.0V</td>
<td>220μF</td>
<td></td>
</tr>
<tr>
<td>12.0V</td>
<td>120μF</td>
<td></td>
</tr>
<tr>
<td>15.0V</td>
<td>100μF</td>
<td></td>
</tr>
</tbody>
</table>

Max. capacitive load for REC3 and REC5 series

<table>
<thead>
<tr>
<th>3W, 5W</th>
<th>Single output</th>
<th>Dual output</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3V</td>
<td>2200μF</td>
<td></td>
</tr>
<tr>
<td>5.0V</td>
<td>1000μF</td>
<td></td>
</tr>
<tr>
<td>9.0V</td>
<td>470μF</td>
<td></td>
</tr>
<tr>
<td>12.0V</td>
<td>220μF</td>
<td></td>
</tr>
<tr>
<td>15.0V</td>
<td>120μF</td>
<td></td>
</tr>
</tbody>
</table>

| ±5.0V  | ±470μF        |             |
| ±9.0V  | ±220μF        |             |
| ±12.0V | ±100μF        |             |
| ±15.0V | ±68μF         |             |

Max. capacitive load for REC7.5 series

<table>
<thead>
<tr>
<th>7.5W</th>
<th>Single output</th>
<th>Dual output</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3V</td>
<td>3300μF</td>
<td></td>
</tr>
<tr>
<td>5.0V</td>
<td>2200μF</td>
<td></td>
</tr>
<tr>
<td>9.0V</td>
<td>680μF</td>
<td></td>
</tr>
<tr>
<td>12.0V</td>
<td>330μF</td>
<td></td>
</tr>
<tr>
<td>15.0V</td>
<td>220μF</td>
<td></td>
</tr>
</tbody>
</table>

| ±5.0V  | ±1000μF       |             |
| ±9.0V  | ±330μF        |             |
| ±12.0V | ±160μF        |             |
| ±15.0V | ±100μF        |             |
Assuming we have a known isolation capacitance \( C_{IS} \) (refer to datasheet) and a known frequency for either the noise or test signal, then the expected leakage current \( i_L \) between input and output circuits can be calculated from the impedance.

The general isolation impedance equation for a given frequency \( f \) is given by:

\[
Z_f = \frac{1}{2\pi f C_{IS}}
\]

For an RB-0505D, the isolation capacitance is 18pF, hence the isolation impedance to a 50Hz test signal is:

\[
Z_{50} = \frac{1}{2\pi \times 50 \times 18 \text{ pF}} = 177 \text{ M}\Omega
\]

If using a test voltage of 1kVrms, the leakage current is:

\[
i_L = \frac{V_{test}}{Z_f} = \frac{1000\text{V}}{177 \text{ M}\Omega} = 5.65 \mu\text{A}
\]

It can be easily observed from these simple equations that the higher the test or noise voltage, the larger the leakage current, also the lower the isolation capacitance, the lower the leakage current. Hence for low leakage current, high noise immunity designs, high isolation DC-DC converters should be selected with an appropriate low isolation capacitance.

**Application Examples**

**Overload Protection**

Although the use of filtering will prevent excessive current at power-on under normal operating conditions, many of the lower cost converters have no protection against an output circuit taking excessive power or even going short-circuit. When this happens, the DC-DC converter will take a large input current to try to supply the output. Eventually the converter will overheat and destroy itself if this condition is not rectified (short circuit overload is only guaranteed for 1 s on an unregulated part).

There are several ways to prevent overload at the outputs destroying the DC-DC converter. The simplest being a straight forward fuse. Sufficient tolerance for inrush current is required to ensure the fuse does not blow on power-on (see figure 8). Another simple scheme that can be applied is a circuit breaker.

There is also the potential to add some intelligence to the overload scheme by either detecting the input current, or the output voltage (see figure 9).

If there is an intelligent power management system at the input, using a series resistor (in place of the series inductor) and detecting the voltage drop across the device to signal the management system can be used. A similar scheme can be used at the output to determine the output voltage, however, if the management system is on the input side, the signal will need to be isolated from the controller to preserve the system isolation barrier (see figure 10).

There are several other current limiting techniques that can be used to detect an overload situation, the suitability of these is left to the designer. The most important thing to consider is how this information will be used. If the system needs to signal to a controller the location or module causing the overload, some form of intelligence will be needed. If the device simply needs to switch off, a simple fuse type arrangement will be adequate.

Unregulated RECOM DC/DC converters usually are short circuit protected only for a short time like 1 second. By option they can be continuous short circuit protected (option /P), then their design is able to withstand the high output current at overload situation without any need for extra circuit protection. All Recom DC-DC converters which include an internal linear regulator have a thermal overload shut-down condition which protects these devices from excessive over-load. If this condition is to be used to inform a power management system, the most suitable arrangement is the output voltage detector (see figure 10a), since this will fall to near zero on shut-down. Wide input range regulated converters offer overload protection / short circuit protection via an internal circuit that interferes with the primary oscillator so the switching is regulated back in situations of overload or output short circuit.
**Input Voltage Drop-Out (brown-outs)**

When the input voltage drops, or is momentarily removed, the output circuit would suffer similar voltage drops. For short period input voltage drops, such as when other connected circuits have an instantaneous current demand, or devices are plugged in or removed from the supply rail while "hot", a simple diode-capacitor arrangement can prevent the output circuit from being effected.

The circuit uses a diode feed to a large reservoir capacitor (typically 47µF electrolytic), which provides a short term reserve current source for the converter, the diode blocking other circuits from draining the capacitor over the supply rail. When combined with an in-line inductor this can also be used to give very good filtering. The diode volt drop needs to be considered in the power supply line under normal supply conditions. A low drop Schottky diode is recommended (see figure 11).

---

**No Load Over Voltage Lock-Out**

Unregulated DC-DC converters are expected to be under a minimum of 10% load, hence below this load level the output voltage is undefined. In certain circuits this could be a potential problem.

The easiest way to ensure the output voltage remains within a specified tolerance, is to add external resistors, so that there is always a minimum 10% loading on the device (see figure 12). This is rather inefficient in that 10% of the power is always being taken by this load, hence only 90% is available to the additional circuitry. Zener diodes on the output are another simple method. It is recommended that these be used with a series resistor or inductor, as when the Zener action occurs, a large current surge may induce signal noise into the system.
DC-DC Converter Applications

Long Distance Supply Lines

When the supply is transmitted via a cable, there are several reasons why using an isolated DC-DC converter is good design practice (see figure 13). The noise pick up and EMC susceptibility of a cable is high compared to a pcb track. By isolating the cable via a DC-DC converter at either end, any cable pick-up will appear as common mode noise and should be self-cancelling at the converters.

Another reason is to reduce the cable loss by using a high voltage, low current power transfer through the cable and reconverting the supply is required through the cable, a cable loss of 44mW.

LCD Display Bias

A LCD display typically requires a positive or negative 24V supply to bias the crystal. The RO-0524S converter was designed specifically for this application. Having an isolated 0V output, this device can be configured as a +24V supply by connecting this to the GND input, or a −24V supply by connecting the +Vo output to GND (see figure 14).

3V/5V Logic Mixed Supply Rails

There has been a lot of attention given to new I.C.’s and logic functions operating at what is rapidly emerging as the standard supply level for notebook and palmtop computers. The 3.3V supply is also gaining rapid acceptance as the defacto standard for personal telecommunications, however, not all circuit functions required are currently available in a 3.3V powered IC. The system designer therefore has previously had only two options available; use standard 5V logic or wait until the required parts are available in a 3V form, neither being entirely satisfactory and the latter possibly resulting in lost market share.

There is now another option, mixed logic functions running from separate supply rails. A single 3.3V line can be combined with a range of DC-DC converters from Recom, to generate voltage levels to run virtually any standard logic or interface IC.

The Recom range includes dual output parts for powering analogue bipolar and amplifier functions (RA/RB series), as well a single output function for localised logic functions (RL/RM, RN/RO series). A typical example might be a RS232 interface circuit in a laptop PC using a 3.3V interface chip (such as the LT1330), which accepts 3.3V logic signals but requires a 5V supply (see figure 16). Recom has another variation on this theme and has developed two 5V to 3.3V step down DC-DC converters (RL-053.3 and R0-053.3). These have been designed to allow existing systems to start incorporating available 3.3V I.C.’s without having to redesign their power supply.

This is particularly important when trying to reduce the overall power demand of a system, but not having available all of the functions at the 3.3V supply.

The main application for this range of devices is system designers, who want to provide some functionality that requires a higher voltage than is available from the supply rail, or for a single localised function. Using a fully isolated supply is particularly useful in interface functions and systems maintaining separate analogue and digital ground lines.

EIA-232 Interface

In a mains powered PC often several supply rails are available to power a RS232 interface. However, battery operated PC’s or remote equipment having a RS232 interface added later, or as an option, may not have the supply rails to power a RS232 interface. Using a RB-0512S is a simple single chip solution, allowing a fully EIA-232 compatible interface to be implemented from a single 5V supply rail, and only 2 additional components (see figure 15).
Isolated Data Acquisition System

Any active system requiring isolation will need a DC-DC converter to provide the power transfer for the isolated circuit. In a data acquisition circuit there is also the need for low noise on the supply line; hence good filtering is required.

The circuit shown (see figure 17) provides a very high isolation barrier by using an RG/RH/RJ/RK converter; to provide the power isolation and SFH610 opto-isolators for the data isolation. An overall system isolation of 2.5kV is achieved.

EMC Considerations

When used for isolating a local power supply and incorporating the appropriate filter circuits as illustrated in Fig. 17), DC-DC converters can present simple elegant solutions to many EMC power supply problems. The range of fixed frequency DC-DC converters is particularly suitable for use in EMC problem situations, as the stable fixed switching frequency gives easily characterised and easily filtered output.

The following notes give suggestions to avoid common EMC problems in power supply circuits.
**Power Supply Considerations**

- Eliminate loops in supply lines (see figure 18).
- Decouple supply lines at local boundaries (use RCL fitters with low Q, see figure 19).
- Place high speed sections close to the power line input, slowest section furthest away (reduces power plane transients, see figure 20).
- Isolate individual systems where possible (especially analogue and digital systems) on both power supply and signal lines (see figure 21).

An isolated DC-DC converter can provide a significant benefit to help reduce susceptibility and conducted emission due to the isolation of both power rail and ground from the system supply. The range of DC-DC converters available from Recom all utilise toroidal power transformers and as such have negligible EMI.

Isolated DC-DC converters are switching devices and as such have a characteristic switching frequency, which may need some additional filtering.

**Interpretation of DC-DC Converter EMC Data**

Electromagnetic compatibility (EMC) of electrical and electronic products is a measure of electrical pollution. Throughout the world there are increasing statutory and regulatory requirements to demonstrate the EMC of end products. In Europe the EC directive 89/336/EEC requires that, any product sold after 1 January 1996 complies with a series of EMC limits, otherwise the product will be prohibited from sale within the EEC and the seller could be prosecuted and fined.

Although DC-DC converters are generally exempt from EMC regulations on the grounds that these are component items, it is the belief of Recom that the information on the EMC of these components can help designers ensure their end product can meet the relevant statutory EMC requirements. It must be remembered however, that the DC-DC converter is unlikely to be the last component in the chain to the mains supply, hence the information quoted needs interpretation by the circuit designer to determine its impact on the final EMC of their system.
The notes given here are aimed at helping the designer interpret the effect the DC-DC converter will have on the EMC of their end product, by describing the methods and rationale for the measurements made. Where possible CISPR and EN standards have been used to determine the noise spectra of the components, however, all of the standards reference to mains powered equipment and interpretation of these specifications is necessary to examine DC supplied devices.

Conducted and Radiated Emissions

There are basically two types of emissions covered by the EC directive on EMC, radiated and conducted. Conducted emissions are those transmitted over wire connecting circuits together and covers the frequency spectrum 150kHz to 30MHz. Radiated are those emissions transmitted via electromagnetic waves in air and cover the frequency spectrum 30MHz to 1GHz. Hence the EC directive covers the frequency spectrum 150kHz to 1GHz, but as two separate and distinct modes of transmission.

The Recom range of DC-DC converters feature toroidal transformers. These have been tested and proved to have negligible radiated noise. The low radiated noise is primarily due to toroidal shaped transformers maintaining the magnetic flux within the core, hence no magnetic flux is radiated by design. Due to the exceptionally low value of radiated emission, only conducted emissions are quoted.

Conducted emissions are measured on the input DC supply line. Unfortunately no standards exist for DC supplies, as most standards cover mains connected equipment. This poses two problems for a DC supplied device, firstly no standard limit lines can be directly applied, since the DC supplied device does not directly connect to the mains, also all reference material uses the earth-ground plane as reference point. In a DC system often the OV is the reference, however, for EMC purposes, it is probably more effective to maintain the earth as the reference, since this is likely to be the reference that the shielding or casing is connected to. Consequently all measurements quoted are referenced to the mains borne earth.

Line Impedance Stabilisation Network (LISN)

It is necessary to ensure that any measurement of noise is from the device under test (DUT) and not from the supply to this device. In mains connected circuits this is important and the mains has to be filtered prior to supply to the DUT. The same approach has been used in the testing of DC-DC converters and the DC supply to the converter was filtered, to ensure that no noise from the PSU as present at the measuring instrument.

A line impedance stabilisation network (LISN) conforming to CISPR 16 specification is connected to both positive and negative supply rails and referenced to mains earth (see figure 22). The measurements are all taken from the positive supply rail, with the negative rail measurement point terminated with 50 Ohm to impedance match the measurement channels.
Shielding

At all times the DUT, LSN’s and all cables connecting any measurement equipment, loads and supply lines are shielded. The shielding is to prevent possible pick-up on cables and DUT from external EMC sources (e.g. other equipment close by). The shielding is referenced to mains earth (see figure 22).

Line Spectra of DC-DC Converters

All DC-DC converters are switching devices, hence, will have a frequency spectra. Fixed input DC-DC converters have fixed switching frequency, for example the RC/RD range of converters has a typical switching frequency of 50kHz. This gives a stable and predictable noise spectrum regardless of load conditions.

If we examine the noise spectrum closely (see figure 23) we can see several distinct peaks, these arise from the fundamental switching frequency and its harmonics (odd line spectra) and the full rectified spectra, at twice the fundamental switching frequency (even line spectra). Quasi-resonant converters, such as the Recom range, have square wave switching waveforms, this produces lower ripple and a higher efficiency than soft switching devices, but has the drawback of having a relatively large spectrum of harmonics.

The EC regulations for conducted interference covers the bandwidth 150kHz to 30MHz. Considering a converter with a 100kHz nominal switching frequency, this would exhibit 299 individual line spectra. There will also be a variation of absolute switching frequency with production variation, hence a part with a 90kHz nominal frequency would have an additional 33 lines over the entire 30MHz bandwidth. Absolute input voltage also produces slight variation of switching frequency (see figure 24). Hence, to give a general level of conducted noise, we have used a 100kHz resolution bandwidth (RBW) to examine the spectra in the data sheets. This wide RBW gives a maximum level over all the peaks, rather than the individual line spectra. This is easier to read as well as automatically compensating for variances in switching frequency due to production variation or differences in absolute input voltage (see figure 25).

The conducted emissions are measured under full load conditions in all cases. Under lower loads the emission levels do fall, hence full load is the worst case condition for conducted line noise.

Temperature Performance of DC-DC Converters

The temperature performance of the DC-DC converters detailed in this book is always better than the quoted operating temperature range. The main reason for being conservative on the operating temperature range is the difficulty of accurately specifying parametric performance outside this temperature range.

There are some limiting factors which provide physical barriers to performance, such as the Curie temperature of the core material used in the DC-DC converter (the lowest Curie temperature material in use at Recom is 125°C). Ceramic capacitors are used almost exclusively in the DC-DC converters because of their high reliability and extended life properties, however, the absolute...
DC-DC Converter Applications

Transfer Moulded (SMD) DC-DC Converters

Production Guideline Application Note

The introduction by Recom of a new and innovative method of encapsulating hybrid DC-DC converters in a transfer moulded (TM) epoxy molding compound plastic has enabled a new range of surface mount (SMD) DC-DC converters to be brought to market, which addresses the component placement with SOIC style handling.

With any new component there are of course new lessons to be learned with the mounting technology. With the Recom SMD DC-DC converters, the lessons are not new as such, but may require different production techniques in certain applications.

Component Materials

Recom SMD converters are manufactured in a slightly different way than the through-hole converters. Instead of potting the PCB board inside a plastic case with conventional epoxy the whole package is molded around the PCB board with epoxy molding compound plastic. This ensures better thermal conductivity from the heat generating components like semiconductors, transformer, etc. inside to the surface from where it can dissipate via convection. This makes them ideal for reflow processes also under the stricter conditions of lead-free soldering temperatures that meet the requirements of the ROHS regulation.

All materials used in RECOM lead-free products are ROHS compliant, thus the total amount of the restricted materials (lead, mercury, cadmium, hexavalent chromium, PBBs and PBDEs) are below the prescribed limits. Detailed chemical analysis reports are available.

Component Placement

Recom SMD DC-DC converters are designed to be handled by placement machines in a similar way to standard SOIC packages. The parts are available either in tubes (sticks) or in reels. The parts can therefore be placed using machines with either vibrational shuttle, gravity feeders, or reel feeders. The vacuum nozzle for picking and placing the components can be the same as used for a standard 14 pin or 18 pin SOIC (typically a 5mm diameter nozzle). An increase in vacuum pressure may be beneficial, due to the heavier weight of the hybrid compared to a standard SOIC part (a typical 14 pin SOIC weighs 0.1g, the Recom SMD DC-DC converter weighs 1.5 ~ 2.7g). It is advisable to consult your machine supplier on the best choice of vacuum nozzle if in doubt. If placing these components by hand, handle the components only by the central body area where there are no component pins.

Component Alignment

The components can be aligned by either optical recognition or manual alignment. If using manual alignment it should be ensured that the tweezers press on the component body and not on the pins. The components themselves are symmetrical along their axis, hence relatively easy to align using either method.

Solder Pad Design

The Recom SMD DC-DC converters are designed on a pin pitch of 2.54mm (0.1") with 1.20mm pad widths and 1.80mm pad lengths.

This allows pads from one part to be used within a PCB CAD package for forming the pad layouts for other SMD converters. These pads are wider than many standard SOIC pad sizes (0.64mm) and CAD packages may not accommodate these pins with a standard SOIC pad pattern. It should be remembered that these components are power supply devices and as such need wider pads and thicker component leads to minimise resistive losses within the interconnects.

Solder Reflow Profile

RECOM's SMD converters are designed to withstand a maximum reflow temperature of 245°C (for max. 30seconds) in accordance with JEDEC STD-020C. If multiple reflow profiles are to be used (i.e. the part is to pass through several reflow ovens), it is recommended that lower ramp rates be used than the maximum specified in JEDEC STD-020C. Continual thermal cycling to this profile could cause material fatigue, if more than 5 maximum ramp cycles are used. In general these parts will exceed the reflow capability of most IC and passive components on a PCB and should prove the most thermally insensitive component to the reflow conditions.
Recommended Solder Reflow Profile:
The following 2 graphs show the typical recommended solder reflow profiles for SMD and through-hole ROHS compliant converters.

The exact values of the profile’s peak and it’s maximum allowed duration is also given in the datasheet of each converter.

Adhesive Requirements
If SM surface mount components are going to be wave soldered (i.e. in a mixed through hole and SMD PCB) or are to be mounted on both sides of a PCB, then it is necessary to use an adhesive to fix them to the board prior to reflow. The adhesive prevents the SMD parts being ‘washed off’ in a wave solder, and being ‘vibrated off’ due to handling on a double sided SMD board.

As mentioned previously, the Recom range of SMD DC-DC converters are heavier than standard SOIC devices. The heavier weight is a due to their size (volume) and internal hybrid construction. Consequently the parts place a larger than usual stress on their solder joints and leads if these are the only method of attachment. Using an adhesive between component body and PCB can reduce this stress considerably. If the final system is to be subjected to shock and vibration testing, then using adhesive attachment is essential to ensure the parts pass these environmental tests.

The Recom SMD DC-DC converters all have a stand-off beneath the component for the application of adhesive to be placed, without interfering with the siting of the component. The method of adhesive dispensing and curing, plus requirements for environmental test and in-service replacement will determine suitability of adhesives rather than the component itself. However, having a thermoset plastic body, thermoset epoxy adhesive bonding between board and component is the recommended adhesive chemistry.

If the reflow stage is also to be used as a cure for a heat cure adhesive, then the component is likely to undergo high horizontal acceleration and deceleration during the pick and place operation. The adhesive must be sufficiently strong in its uncured (green) state, in order to keep the component accurately placed.

Adhesive Placement
The parts are fully compatible with the 3 main methods of adhesive dispensing; pin transfer, printing and dispensing. The method of placing adhesive will depend on the available processes in the production line and the reason for using adhesive attachment. For example, if the part is on a mixed though-hole and SMD board, adhesive will have to be placed and cured prior to reflow. If using a SMD only board and heat cure adhesive, the reflow may be used as the cure stage. If requiring adhesive for shock and vibration, but using a conformal coat, then it may be possible to avoid a separate adhesive altogether, and the coating alone provides the mechanical restraint on the component body.

Patterns for dispensing or printing adhesive are given for automatic lines. If dispensing manually after placement the patterns for UV cure are easily repeated using a manual syringe (even if using heat cure adhesive). If dispensing manually, dot height and size are not as important, and the adhesive should be applied after the components have been reflowed. When dispensing after reflow, a chip underfill formulation adhesive would be the preferred choice. These types ‘wick’ under the component body and offer a good all round adhesion from a single dispensed dot. The patterns allow for the process spread of the stand-off on the component, but do not account for the thickness of the PCB tracks.
If thick PCB tracks are to be used, a grounded copper strip should be laid beneath the centre of the component (care should be exercised to maintain isolation barrier limits). The adhesive should not retard the pins reaching their solder pads during placement of the part, hence low viscosity adhesive is recommended. The height of the adhesive dot, its viscosity and slumping properties are critical. The dot must be high enough to bridge the gap between board surface and component, but low enough not to slump and spread, or be squeezed by the component, and so contaminate the solder pads.

If wishing to use a greater number of dots of smaller diameter (common for pin transfer methods), the dot pattern can be changed, by following a few simple guidelines. As the number of dots is doubled their diameter should be halved and centres should be at least twice the printed diameter from each other, but the dot height should remain at 0.4mm. The printed dot should always be positioned by at least its diameter from the nearest edge of the body to the edge of the dot. The number of dots is not important, provided good contact between adhesive and body can be guaranteed, but a minimum of 2 is recommended.

Cleaning
The thermoset plastic encapsulating material used for the Recom range of surface mount DC-DC converters is not fully hermetically sealed. As with all plastic encapsulated active devices, strongly reactive agents in hostile environments can attack the material and the internal parts, hence cleaning is recommended in inert solutions (e.g. alcohol or water based solvents) and at room temperature in an inert atmospheres (e.g. air or nitrogen).

A batch or linear aqueous cleaning process would be the preferred method of cleaning using a deionised water solution.

Vapour Phase Reflow Soldering
Vapour phase soldering is a still upcoming soldering practice; therefore there are no standard temperature profiles available. Principally, the Lead-free Soldering Profile recommended by RECOM can be used for vapour phase soldering. RECOM has tested large quantities of 8-pin and 10-pin SMD converters and recommends as an absolute maximum condition 240°C for 90s dwell time. In standard applications with small sized components on a pcb, 230°C and shorter dwell times will still deliver good results. After discussions with various contract manufacturers, we recommended that the temperature gradients used during preheat and cooling phases are between 0.5 K/s up to 3 K/s.

Other form factors than 8-pin or 10-pin SMD-packages have not been tested under vapour phase conditions. Please contact RECOM in this case.

Custom DC-DC Converters
In addition to the standard ranges shown in this data book, Recom have the capability to produce custom DC-DC converters designed to your specific requirements. In general, the parts can be rapidly designed using computer based CAD tools to meet any input or output voltage requirements within the ranges of Recom standard products (i.e. up to 48V at either input or output). Prototype samples can also be produced in short timescales. Custom parts can be designed to your specification, or where the part fits within a standard series, the generic series specification can be used. All custom parts receive the same stringent testing, inspection and quality procedures, as standard products. However there is a minimum order quantity as this additional documentations and administrative tasks must be covered in terms of costs. A general figure for this MOQ can be around 3000pcs of low wattage converters (0,25pcs ~ 2W), 1000pcs medium sized wattage (2W~15W) and 500pcs for higher wattages (> 20W).Recom custom parts are used in many applications, which are very specific to the individual customer, however, some typical examples are:
- ECL Logic driver
- Multiple cell battery configurations
- Telecommunications line equipment
- Marine apparatus
- Automotive electronics
- LCD display power circuitry
- Board level instrumentation systems

To discuss your custom DC-DC converter requirements, please contact Recom technical support desk or your local distributor.
**Unregulated Single Output**

**Unregulated Dual Output**

**Unregulated Dual Isolated Output**
RU, RLUZ

**Post-Regulated Single Output**
RZ, RSZ (P), RY-xxxxS, RX-xxxxS, RY-SCP, REC1.5-xxxxSR/H1, REC1.8-xxxxSR/H1, REC2.2-xxxxSR/H1, REC3-xxxxSR/H1

**Post-Regulated Dual Output**
RY-xxxxS, RX-xxxxS, RY-DCP, REC2.2-xxxxDR/H1, REC3-xxxxDR/H1
Regulated Single Output
RSO, RS, REC2.2-xxxxGRW, RW-xxxxG, REC3-xxxxSRW(Z)/H*, REC5-xxxxSRW(Z)/H*, REC7.5-xxxxSRW/AM/H*, REC10-xxxxSRW(Z)/H*, REC15-
xxxxSRW(Z)/H, REC20-xxxxSRWB(Z)/H, REC30-xx( 12,15, 24V )SRWZ/H, REC40-xx( 12,15, 24V )SRW/H, REC40-xx( 12,15, 24V )SRWB/H

Regulated Dual Output
RSO-xxxxD, RS-xxxxD, REC2.2-xxxxDRW, RW-xxxxD, REC3-xxxxDRW(Z)/H*, REC5-xxxxDRW(Z)/H*, REC7.5-xxxxDRW/AM/H*,
REC10-xxxxDRW(Z)/H, REC15-xxxxDRW/Z)/H, REC20-xxxxDRWB(Z)/H, REC30-xxxxDRWZ/H, REC40-xxxxDRWB/H

Regulated Dual Isolated Output
REC3-DRWI
Regulated Single Output

REC20-xxxxSRW/H, REC30-xx(1.8, 2.5, 3.3, 5V)SRWZ/H, REC40-xx(1.8, 2.5, 3.3, 5V)SRWB/H

+Vin

PWM Controller

- Vin

Switch Control

Isolation

Reference & Error AMP

+ Vout

Com

ON/OFF Control

Trim
Common Mode Chokes for EMC

Recom offers a range of Common Mode Chokes useful for EMI Filtering to meet the requirements of EN-55022, Class B. The component values given are suggested values and may need to be optimised to suit the application. The effectiveness of any filter network is heavily dependent on using quality capacitors, the layout of the board and having a low impedance path to ground. See section on filtering elsewhere in the Application Notes for more details.

EMC Filter Suggestion

Component Values

**REC3–REC7.5**

RP08  
Vin = 12/24VDC nom., C1=4.7µF/50V MLCC, C2=100µF/50V Electrolytic, C3,C4=1nF/2kV MLCC, CMC-01
Vin = 48VDC nom., C1=2.2µF/100V MLCC, C2=27µF/100V Electrolytic, C3,C4=1nF/2kV MLCC, CMC-02

**REC10–REC20**

RP10–RP20  
Vin = 12/24VDC nom., C1=4.7µF/50V MLCC, C2=100µF/50V Electrolytic, C3,C4=1nF/2kV MLCC, CMC-03
Vin = 48VDC nom., C1=2.2µF/100V MLCC, C2=27µF/100V Electrolytic, C3,C4=1nF/2kV MLCC, CMC-04

**CMC-01/ CMC-02**

**CMC-03/ CMC-04**

<table>
<thead>
<tr>
<th>Component</th>
<th>Inductance</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMC-1</td>
<td>620µHx2</td>
<td>1.7A</td>
</tr>
<tr>
<td>CMC-2</td>
<td>930µHx2</td>
<td>1.1A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Inductance</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMC-3</td>
<td>1300µHx2</td>
<td>4.7A</td>
</tr>
<tr>
<td>CMC-4</td>
<td>3000µHx2</td>
<td>1.7A</td>
</tr>
</tbody>
</table>
General Test Set-Up

Note: If the converter is under test with remote sense pins, connect these pins to their respective output pins. All tests are made in “Local sensing” mode.

Input Voltage Range

The minimum and maximum input voltage limits within which a converter will operate to specifications.

PI Filter

An input filter, consisting of two capacitors, is connected in parallel with a series inductor to reduce input reflected ripple current.

Output Voltage Accuracy

With nominal input voltage and rated output load from the test set-up, the DC output voltage is measured with an accurate, calibrated DC voltmeter. Output voltage accuracy is the difference between the measured output voltage and specified nominal value as a percentage. Output accuracy (as a %) is then derived by the formula:

\[
\frac{V_{\text{out}} - V_{\text{nom}}}{V_{\text{nom}}} \times 100
\]

Vnom is the nominal, output specified in the converter data sheet.

Voltage Balance

For a multiple output power converter, the percentage difference in the voltage level of two outputs with opposite polarities and equal nominal values.

Line Regulations

Make and record the following measurements with rated output load at +25°C:

- Output voltage at nominal line (input) voltage.
- Output voltage at high line (input) voltage.
- Output voltage at low line (input) voltage.

The line regulation is Vout M (the maximum of the two deviations of output) for the value at nominal input in percentage.

\[
\frac{V_{\text{out M}} - V_{\text{out N}}}{V_{\text{out N}}} \times 100
\]
Powerline – Definitions and Testing

Load Regulation

Make and record the following measurements with rated output load at +25°C:

● Output voltage with rated load connected to the output. (Vout FL)
● Output voltage with no load or the minimum specified load for the DC-DC converter. (Vout ML)

Load regulation is the difference between the two measured output voltages as a percentage of output voltage at rated load.

\[
\frac{V_{\text{out ML}} - V_{\text{out FL}}}{V_{\text{out FL}}} \times 100
\]

Efficiency

The ratio of output load power consumption to input power consumption expressed as a percentage. Normally measured at full rated output power and nominal line conditions.

Switching Frequency

The rate at which the DC voltage is switched in a DC-DC converter or switching power supply.

Output Ripple and Noise

Because of the high frequency content of the ripple, special measurement techniques must be employed so that correct measurements are obtained. A 20MHz bandwidth oscilloscope is used, so that all significant harmonics of the ripple spike are included.

This noise pickup is eliminated as shown in Figure 3, by using a scope probe with an external connection ground or ring and pressing this directly against the output common terminal of the power converter, while the tip contacts the voltage output terminal. This provides the shortest possible connection across the output terminals.

Figure 3:
Output Ripple and Noise (continued) Figure 4 shows a complex ripple voltage waveform that may be present on the output of a switching power supply. There are three components in the waveform, first is a charging component that originates from the output rectifier and filter, then there is the discharging component due to the load discharging the output capacitor between cycles, and finally there are small high frequency switching spikes imposed on the low frequency ripple.

Transient Recovery Time The time required for the power supply output voltage to return to within a specified percentage of rated value, following a step change in load current.

Current Limiting output current is limited to prevent damage of the converter at overload situations.

Fold Back Current Limiting A method of protecting a power supply from damage in an overload condition, reducing the output current as the load approaches short circuit.
**Powerline – Definitions and Testing**

### Isolation

The electrical separation between the input and output of a converter, consisting of resistive and capacitive isolation, normally determined by transformer characteristics and circuit spacing.

### Break-Down Voltage

The maximum continuous DC voltage, which may be applied between the input and output terminal of a power supply without causing damage. Typical break-down voltage for DC-DC converters is 500VDC minimum.

### Temperature Coefficient

With the power converter in a temperature test chamber with rated output load, make the following measurements:

- Output voltage at +25°C ambient temperature.
- Set the chamber for maximum operating ambient temperature and allow the power converter to stabilize for 15 to 30 minutes. Measure the output voltage.
- Set the chamber to minimum operating ambient temperature and allow the power converter to stabilize for 15 to 30 minutes. Divide each percentage voltage deviation from the +25°C ambient value by the corresponding temperature change from +25°C ambient.

The temperature coefficient is the higher one of the two values calculated above, expressed as percent per change centigrade.

### Ambient Temperature

The temperature of the still-air immediately surrounding an operating power supply.

### Operating Temperature Range

The range of ambient or case temperature within a power supply at which it operates safely and meets its specifications.

### Storage Temperature Range

The range of ambient temperatures within a power supply at non-operating condition, with no degradation in its subsequent operation.

---

**Figure 7:** The temperature of the still-air immediately surrounding an operating power supply.
Output Voltage Trimming:

Some converters from our Powerline offer the feature of trimming the output voltage in a certain range around the nominal value by using external trim resistors. Because different series use different circuits for trimming no general equation can be given for calculating the trim-resistors. Following trim-tables give values for choosing these trim-resistors. If voltages between the given trim-points are required a linear approximation of the next points is possible or using trimmable resistors may be considered.

**RP20-, RP30- XX1.8S**

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>1,818</td>
<td>1,836</td>
<td>1,854</td>
<td>1,872</td>
<td>1,89</td>
<td>1,908</td>
<td>1,926</td>
<td>1,944</td>
<td>1,962</td>
<td>1,98</td>
</tr>
<tr>
<td>RU =</td>
<td>11,88</td>
<td>5,26</td>
<td>3,09</td>
<td>2,00</td>
<td>1,35</td>
<td>0,92</td>
<td>0,61</td>
<td>0,38</td>
<td>0,20</td>
<td>0,06 KOhms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trim down</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>1,782</td>
<td>1,764</td>
<td>1,746</td>
<td>1,728</td>
<td>1,71</td>
<td>1,692</td>
<td>1,674</td>
<td>1,656</td>
<td>1,638</td>
<td>1,62</td>
</tr>
<tr>
<td>RD =</td>
<td>14,38</td>
<td>6,50</td>
<td>3,84</td>
<td>2,51</td>
<td>1,71</td>
<td>1,17</td>
<td>0,79</td>
<td>0,50</td>
<td>0,27</td>
<td>0,10 KOhms</td>
</tr>
</tbody>
</table>

**RP20-, RP30- XX2.5S**

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>2,525</td>
<td>2,55</td>
<td>2,575</td>
<td>2,6</td>
<td>2,625</td>
<td>2,65</td>
<td>2,675</td>
<td>2,7</td>
<td>2,725</td>
<td>2,75</td>
</tr>
<tr>
<td>RU =</td>
<td>36,65</td>
<td>16,57</td>
<td>9,83</td>
<td>6,45</td>
<td>4,42</td>
<td>3,06</td>
<td>2,09</td>
<td>1,37</td>
<td>0,80</td>
<td>0,35 KOhms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trim down</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>2,475</td>
<td>2,45</td>
<td>2,425</td>
<td>2,4</td>
<td>2,375</td>
<td>2,35</td>
<td>2,325</td>
<td>2,3</td>
<td>2,275</td>
<td>2,25</td>
</tr>
<tr>
<td>RD =</td>
<td>50,20</td>
<td>22,62</td>
<td>13,49</td>
<td>8,94</td>
<td>6,21</td>
<td>4,39</td>
<td>3,09</td>
<td>2,12</td>
<td>1,36</td>
<td>0,76 KOhms</td>
</tr>
</tbody>
</table>

**RP15-, RP20-, RP30-, RP40- xx3.3S**

**RP40-, xx3.305T (Trim for +3.3V)**

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RU =</td>
<td>57,96</td>
<td>26,17</td>
<td>15,58</td>
<td>10,28</td>
<td>7,11</td>
<td>4,99</td>
<td>3,48</td>
<td>2,34</td>
<td>1,46</td>
<td>0,75 KOhms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trim down</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>3,267</td>
<td>3,234</td>
<td>3,201</td>
<td>3,168</td>
<td>3,135</td>
<td>3,102</td>
<td>3,069</td>
<td>3,036</td>
<td>3,003</td>
<td>2,97</td>
</tr>
<tr>
<td>RD =</td>
<td>69,43</td>
<td>31,23</td>
<td>18,49</td>
<td>12,12</td>
<td>8,29</td>
<td>5,74</td>
<td>3,92</td>
<td>2,56</td>
<td>1,50</td>
<td>0,65 KOhms</td>
</tr>
</tbody>
</table>

**RP15-, RP20-, RP30-, RP40- (Trim for +5V)**

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>5,05</td>
<td>5,1</td>
<td>5,15</td>
<td>5,2</td>
<td>5,25</td>
<td>5,3</td>
<td>5,35</td>
<td>5,4</td>
<td>5,45</td>
<td>5,5</td>
</tr>
<tr>
<td>RU =</td>
<td>43,22</td>
<td>18,13</td>
<td>10,60</td>
<td>6,97</td>
<td>4,83</td>
<td>3,42</td>
<td>2,43</td>
<td>1,68</td>
<td>1,11</td>
<td>0,65 KOhms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trim down</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>4,95</td>
<td>4,9</td>
<td>4,85</td>
<td>4,8</td>
<td>4,75</td>
<td>4,7</td>
<td>4,65</td>
<td>4,6</td>
<td>4,55</td>
<td>4,5</td>
</tr>
<tr>
<td>RD =</td>
<td>39,42</td>
<td>19,00</td>
<td>11,58</td>
<td>7,74</td>
<td>5,40</td>
<td>3,82</td>
<td>2,68</td>
<td>1,82</td>
<td>1,15</td>
<td>0,61 KOhms</td>
</tr>
</tbody>
</table>
# Powerline – Definitions and Testing

## RP15-, RP20- xx05D

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>10.1</td>
<td>10.2</td>
<td>10.3</td>
<td>10.4</td>
<td>10.5</td>
<td>10.6</td>
<td>10.7</td>
<td>10.8</td>
<td>10.9</td>
<td>11</td>
<td>Volts</td>
</tr>
<tr>
<td>R_U =</td>
<td>90.50</td>
<td>40.65</td>
<td>24.06</td>
<td>15.76</td>
<td>10.79</td>
<td>7.47</td>
<td>5.10</td>
<td>3.33</td>
<td>1.95</td>
<td>0.84</td>
<td>KOhms</td>
</tr>
<tr>
<td>Trim down</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>Vout =</td>
<td>9.9</td>
<td>9.8</td>
<td>9.7</td>
<td>9.6</td>
<td>9.5</td>
<td>9.4</td>
<td>9.3</td>
<td>9.2</td>
<td>9.1</td>
<td>9</td>
<td>Volts</td>
</tr>
<tr>
<td>R_D =</td>
<td>109.06</td>
<td>48.94</td>
<td>28.87</td>
<td>18.83</td>
<td>12.81</td>
<td>8.79</td>
<td>5.92</td>
<td>3.77</td>
<td>2.10</td>
<td>0.76</td>
<td>KOhms</td>
</tr>
</tbody>
</table>

## RP15-, RP20-, RP30-, RP40-

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>12.12</td>
<td>12.24</td>
<td>12.36</td>
<td>12.48</td>
<td>12.6</td>
<td>12.72</td>
<td>12.84</td>
<td>12.96</td>
<td>13.08</td>
<td>13.2</td>
<td>Volts</td>
</tr>
<tr>
<td>R_U =</td>
<td>1019.45</td>
<td>257.41</td>
<td>134.39</td>
<td>84.06</td>
<td>56.68</td>
<td>39.47</td>
<td>27.65</td>
<td>19.03</td>
<td>12.47</td>
<td>7.30</td>
<td>KOhms</td>
</tr>
<tr>
<td>Trim down</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>Vout =</td>
<td>11.88</td>
<td>11.76</td>
<td>11.64</td>
<td>11.52</td>
<td>11.4</td>
<td>11.28</td>
<td>11.16</td>
<td>11.04</td>
<td>10.92</td>
<td>10.8</td>
<td>Volts</td>
</tr>
<tr>
<td>R_D =</td>
<td>270.20</td>
<td>149.63</td>
<td>95.76</td>
<td>65.24</td>
<td>45.59</td>
<td>31.88</td>
<td>21.77</td>
<td>14.01</td>
<td>7.86</td>
<td>2.87</td>
<td>KOhms</td>
</tr>
</tbody>
</table>

## RP15-, RP20, RP30-

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_U =</td>
<td>210.51</td>
<td>96.13</td>
<td>57.18</td>
<td>37.54</td>
<td>25.71</td>
<td>17.80</td>
<td>12.14</td>
<td>7.89</td>
<td>4.58</td>
<td>1.93</td>
<td>KOhms</td>
</tr>
<tr>
<td>Trim down</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>Vout =</td>
<td>23.76</td>
<td>23.52</td>
<td>23.28</td>
<td>23.04</td>
<td>22.8</td>
<td>22.56</td>
<td>22.32</td>
<td>22.08</td>
<td>21.84</td>
<td>21.6</td>
<td>Volts</td>
</tr>
<tr>
<td>R_D =</td>
<td>283.54</td>
<td>125.47</td>
<td>73.95</td>
<td>48.40</td>
<td>33.14</td>
<td>22.99</td>
<td>15.76</td>
<td>10.34</td>
<td>6.13</td>
<td>2.76</td>
<td>KOhms</td>
</tr>
</tbody>
</table>

## RP15-, RP20-, RP30-, RP40-

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>15.15</td>
<td>15.3</td>
<td>15.45</td>
<td>15.6</td>
<td>15.75</td>
<td>15.9</td>
<td>16.05</td>
<td>16.2</td>
<td>16.35</td>
<td>16.5</td>
<td>Volts</td>
</tr>
<tr>
<td>R_U =</td>
<td>455.67</td>
<td>192.89</td>
<td>111.48</td>
<td>71.85</td>
<td>48.40</td>
<td>32.90</td>
<td>21.90</td>
<td>13.68</td>
<td>7.31</td>
<td>2.23</td>
<td>KOhms</td>
</tr>
<tr>
<td>Trim down</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>R_D =</td>
<td>449.01</td>
<td>210.22</td>
<td>125.38</td>
<td>81.89</td>
<td>55.46</td>
<td>37.68</td>
<td>24.92</td>
<td>15.30</td>
<td>7.80</td>
<td>1.78</td>
<td>KOhms</td>
</tr>
</tbody>
</table>

## RP15-, RP20-, RP30-

<table>
<thead>
<tr>
<th>Trim up</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vout =</td>
<td>30.3</td>
<td>30.6</td>
<td>30.9</td>
<td>31.2</td>
<td>31.5</td>
<td>31.8</td>
<td>32.1</td>
<td>32.4</td>
<td>32.7</td>
<td>33</td>
<td>Volts</td>
</tr>
<tr>
<td>R_U =</td>
<td>306.24</td>
<td>129.65</td>
<td>75.39</td>
<td>49.05</td>
<td>33.49</td>
<td>23.21</td>
<td>15.92</td>
<td>10.48</td>
<td>6.26</td>
<td>2.90</td>
<td>KOhms</td>
</tr>
<tr>
<td>Trim down</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>%</td>
</tr>
<tr>
<td>Vout =</td>
<td>29.7</td>
<td>29.4</td>
<td>29.1</td>
<td>28.8</td>
<td>28.5</td>
<td>28.2</td>
<td>27.9</td>
<td>27.6</td>
<td>27.3</td>
<td>27</td>
<td>Volts</td>
</tr>
<tr>
<td>R_D =</td>
<td>300.42</td>
<td>142.30</td>
<td>85.77</td>
<td>56.73</td>
<td>39.05</td>
<td>27.16</td>
<td>18.60</td>
<td>12.16</td>
<td>7.13</td>
<td>3.10</td>
<td>KOhms</td>
</tr>
</tbody>
</table>
Powerline - Heat Sinks

7G-0020A (9.5°C/W)

7G-0026A (7.8°C/W)
Powerline - Heat Sinks

7G-0011A (8.24°C/W)

7G-0022A (INNOLINE)
<table>
<thead>
<tr>
<th>No.</th>
<th>Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>RO, RM, RE, ROM, RB, RBM, RK, RH, RP, RU, RI, RD, REZ, RKZ, RUF, RY, RxxTR, R-78xx</td>
</tr>
<tr>
<td>2.</td>
<td>RS, RSO</td>
</tr>
<tr>
<td>3.</td>
<td>RL, RN, RF, RA, RC, RX</td>
</tr>
<tr>
<td>4.</td>
<td>RSS, RSD, RQS, RQD, RZ</td>
</tr>
<tr>
<td>5.</td>
<td>RTD, RTS, RSZ, R-78Axx SMD</td>
</tr>
<tr>
<td>6.</td>
<td>RV, RW, RxxPxx, RxxP2xx</td>
</tr>
<tr>
<td>7.</td>
<td>R5, R6, R7, REC1.5-, REC1.8-, REC3-, REC5-, REC7.5-</td>
</tr>
<tr>
<td>8.</td>
<td>RAA</td>
</tr>
<tr>
<td>9.</td>
<td>RP08, RP12</td>
</tr>
<tr>
<td>10.</td>
<td>RP08-SMD, REC2.2-SMD, REC3-SMD, REC5-SMD, REC7.5-SMD</td>
</tr>
<tr>
<td>11.</td>
<td>REC10, REC15, REC20, REC30, REC40</td>
</tr>
<tr>
<td>12.</td>
<td>RP10, RP15, RP20, RP30, RP40</td>
</tr>
<tr>
<td>13.</td>
<td>RP40-E</td>
</tr>
</tbody>
</table>

TUBE LENGTH = 520mm ± 1.0

TUBE LENGTH = 520mm ± 1.5
3. TUBE LENGTH = 520mm ± 1.0

4. TUBE LENGTH = 530mm ± 2.0

5. TUBE LENGTH = 530mm ± 2.0

6. TUBE LENGTH = 520mm ± 2.0

7. TUBE LENGTH = 520mm ± 2.0

8. TUBE LENGTH = 520mm ± 2.0

9. TUBE LENGTH = 252mm ± 2.0

10. TUBE LENGTH = 538mm ± 2.0
11. TUBE LENGTH = 292mm ± 2.0

12. TUBE LENGTH = 254mm ± 2.0

13. TUBE LENGTH = 256mm ± 5.0
RSS-xxxx & RQS-xxxx tape outline dimensions

Spocket hole  Ø1.50±0.1/-0
Spocket hole tolerance over any 10 pitches ±0.2

All dimensions in mm xx.xx ±0.1

1. 10 sprocket hole pitch cumulative tolerance ±0.20
2. All dimensions meet EIA-481-2 requirements
3. Component load per 13" reel : 500 pcs
4. The diameter of disc center hole is 13.0mm
RSD-xxxx, RQD-xxxx & RZ-xxxx tape outline dimensions

Spocket hole  01.50+0.1/-0
Spocket hole tolerance over any 10 pitches ±0.2

All dimensions in mm  xx.xx ±0.1

1. 10 sprocket hole pitch cumulative tolerance ±0.20
2. All dimensions meet EIA-481-2 requirements
3. Component load per 13" reel : 500 pcs
4. The diameter of disc center hole is 13.0mm
RSZ-xxx, RTS-xxx, RTD-xxx & R-78Axx-xxSMD tape outline dimensions

Spocket hole Ø1.50+0.1/-0
Spocket hole tolerance over any 10 pitches ±0.2

All dimensions in mm xx.xx ±0.1

1. 10 sprocket hole pitch cumulative tolerance ±0.20
2. All dimensions meet EIA-481-2 requirements
3. Component load per 13" reel : 500 pcs
4. The diameter of disc center hole is 13.0mm